DEVELOPMENT OF A DYE DETECTION SYSTEM CONCENTRATION IN WATER USING DIGITAL IMAGES

Willian M. Oliveira[1], Yasmim R. Meirelles[2], Mário C. Silva Junior[1], Jorge D. A. Bellido[2], Lisbeth Z. Melgar[2], Heber T. Souza[3]

[1]*CELTA, Center for Studies in Eletronic Engineering and Automation, Federal University of São João Del-Rei, Campus Ouro Branco*
Rodovia MG 443, KM 7, Ouro Branco, 36420-000, Minas Gerais, Brazil
william130996@yahoo.com.br, mariocupertino@gmail.com
[2]*Dept. of Chemical Engineering, Federal University of São João Del-Rei, Campus Ouro Branco*
Rodovia MG 443, KM 7, Ouro Branco, 36420-000, Minas Gerais, Brazil
yasmim.meirelles@hotmail.com, jorgeb@ufsj.edu.br, lisbethzm@ufsj.edu.br
[3]*Dept. of Telecommunications and Mechatronics Engineering, Federal University of São João Del-Rei, Campus Ouro Branco*
Rodovia MG 443, KM 7, Ouro Branco, 36420-000, Minas Gerais, Brazil
heber@ufsj.edu.br

Abstract. This study aims to detect dyes at different concentrations and diluted in water using RGB digital images captured with a webcam dispositive. This detection is a low-cost alternative for the spectrophotometer, an equipment consolidated for this type of application. From the captured images, it was cut areas with 40x100 pixels and the average value for these pixels were used during the image's process, creating 4 types of models. It compared these models results with the obtained ones by the spectrophotometer. The greater result obtained by the logarithm model referred to the R band normalized with a quadratic approximation, presenting a correlation coefficient of 0.9912. Therefore, it concluded that the use of this technology has the potential to detect different dye concentrations with the spectrophotometer backing.

Keywords: digital imagens, RGB, spectrophotometer.

1 Introduction

Textile dyes are largely used in industry to pigment different types of fabric where its application is performedin three stages: mounting, fixation and final treatment [1]. The fixation of the dye molecule in the fabric fibers is commonly made in an aqueous solution and it can involve 4 interactions: ionic, hydrogen, Van der Waals and covalent bonds. However, not all dye material is fixed in the fabric, resulting in a residue that needs a treatment before being disposed of in the river network.

To develop treatment techniques, it is necessary to attend a great number of samples with different dye concentrations where the analysis can be performed using spectrophotometry, method responsible for the absorbance analysis of a solution. Spectrophotometry is accomplished through a spectrophotometer equipment capable of casting a light beam in a determined spectrum wavelength and then determining the quantity of light absorbed by the substance. Using samples with known concentrations, it is possible to obtain a model correlating the substance absorbance with the solution concentration. The spectrophotometer presents as advantages its greaterprecision and easy reading; however, its disadvantages are its limited portability and high acquisition and maintenance cost [2].

As an alternative, this study presented a method to calculate the samples absorbencies using captured color images in RGB standard. The RGB images are composed by a three-dimensional matrix in red (R), green (G) andblue (B) channels, which represent the primary colors of the color subtractive system [3]. These image treatmentscan supply information of the object's color quantity and promote the identification of different dye concentrations in aqueous solutions.

Therefore, the presented work aims to detect different levels of dye concentration in water usingimage digital treatment and as specific goals, there are the development of mathematical models, obtained by theimages, to evaluate the RGB band correlations with the absorbencies engendered by the spectrophotometer.

2 Materials and Methods

For the image's accomplishment, a controlled ambient was built aiming to avoid sudden changes in brightness during the data collection and hence, to avoid the influence of external light in results. This ambient is presented by Fig. 1. It used a box with its interior filled with paper to uniform the brightness. The background was used to normalize the effects in the brightness variation, once webcams have a factory setting that promotes the automatic brightness correction, altering the pixel values.

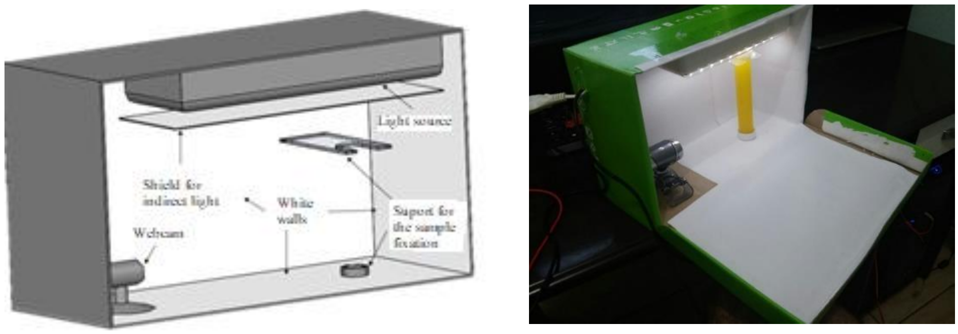

Figure 1. Controlled ambient for the images acquisition.

A shield was placed beneath the light source to avoid reflection on the test tubes with samples of different dye concentrations. Therefore, the ambient light was uniform and indirect. To test the potentiality of using the image detection on different concentrations, it was performed an analysis where it was used the follow concentrations of Congo red dye: 0.225, 0.45, 1.87, 3.75, 7.5, 10, 12.5, 15, 20, 25, 30, 40, 50, 60 mg. L-1. The dye was placed in the test tubes and of each concentration was performed 3 replicates, being a total of 42 samples. Four samples were created with unknown and aleatory concentrations for the detection analysis.

Each sample was captured in an image and sequentially, it was collected a liquid portion to insert on the spectrophotometer UV-VIS, manufactured by Shimadzu. As the spectrophotometer is a trustful commercial equipment for dye concentration identification, it was used to evaluate the images potential and to inform its correlations with the data obtained by its processing. All equipment used in this study were available on Department of Chemical Engineering of Federal University of São João del-Rei, Campus Alto Paraopeba.

After the images' acquisition, it was used for the image's treatment, a method developed by Kehoe and Penn [4]. First, a cut was performed on the images in two areas, 40 x 100 pixels, one referring to the test tube center and the other in accordance with the background. The cut areas were processed and the band R pixel average values were used to build the regression models, responsible also for the correlation with the data supplied by spectrophotometer.

The image obtained by a camera is the reflected light on the object and therefore, when calculating the pixel's average values, there was a value linked to the reflected light on the analyzed sample. This reflectance was related to the absorbance, absorbed light by the object, through eq. (1):

$$A = -\log\frac{ln}{lb} \tag{1}$$

Where ln is the pixel average values of the R band on the test tube cut area and lb is the pixel average valuesof the background cut area. The A is the absorbance calculated from the images, being a logarithmic correlation. Dividing ln by lb, it also normalized the values, reducing possible brightness variations.

To evaluate the relation between the images and the spectrophotometer data, four analyses were performed.Two experiments related the calculated absorbance (A), using linear and quadratic regression, with the values supplied by the spectrophotometer, which are measured absorbances. The other two experiments related ln/lb withthe data supplied by the spectrophotometer, also using linear and quadratic regression. Nevertheless, it calculatedthe correlation coefficient among the tests.

3 Results and Discussion

The obtained data in the image treatment of the samples with unknown concentration were applied in the four regression models (linear A, quadratic A, linear ln/lb and quadratic ln/lb). The results observed on this application can be seen on Tab. 1. The image results were also confronted with the obtained values by the regression model created using the spectrophotometer.

The quadratic A model promoted the lowest variation between the values and the spectrophotometer model,exhibiting a quadratic tendency of image pixel values distribution through the different concentrations.

Figure 2 presents the spectrophotometer and quadratic A models for the tested concentrations. By these graphics, it is possible to certify the data veracity of Tab. 1.

Table 1. Concentration in $mg.L^{-1}$.

Sample	Spectrophotometer	Linear A	Quadratic A	Linear ln/lb	Quadratic ln/lb
1	20.7672	23.6515	20.9401	24.5132	21.0370
2	4.8975	3.3659	4.0784	3.2461	3.9575
3	5.6134	5.7594	5.7384	5.8711	5.5655
4	14.9682	15.4433	13.3545	16.1714	13.2358

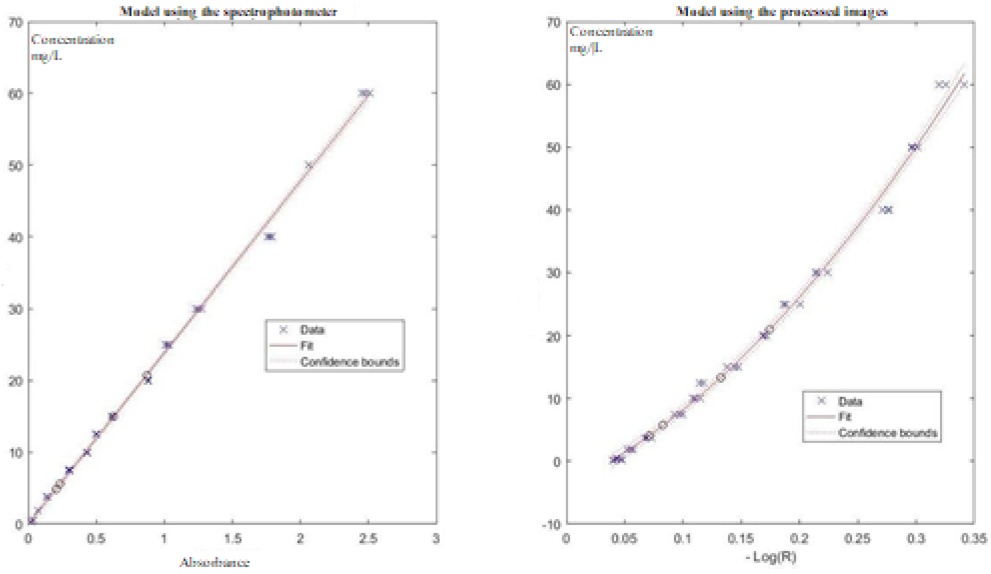

Figure 2. Spectrophotometer and quadratic A models against concentrations (mg.L^{-1}).

The correlation coefficient value between spectrophotometer and quadratic A absorbances was 0.9912. Thisindicated a great correlation between these variables and a potential to use image detection for different concentrations of the Congo red dye.

4 Conclusions

The results presented the possibility to detect different concentration levels for Congo red dye in water usingdigital image analysis. The regression models and the correlation coefficient confirmed the great relation betweenthe information supplied by the images and the absorbance values given by the spectrophotometer.

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